Remarks

The specification and claims 1 and 9 have been amended herein. Claims 1-17 remain pending in the subject application.

Substitute Specification

The Office action states that the substitute specification submitted on April 6, 2005, is not accepted for reasons stated in the previous Office action. The previous Office action, dated June 14, 2005, states that a substitute specification must be submitted showing all changes relative to the immediate prior version. However, a substitute specification showing markings (i.e., redlined) was submitted with the Request for Continued Examination filed April 6, 2005, and a substitute specification without markings (i.e., clean) excluding the claims was attached to the previous Amendment (filed September 14, 2005).

A substitute specification showing markings (i.e., redlined) and a substitute specification without markings (i.e., clean) excluding the claims are resubmitted with this amendment. The substitute specification contains no new matter. In this amendment, references to the specification are made with respect to the clean substitute specification.

Objection to Amendment - 35 U.S.C. § 132(a)

Applicant respectfully requests reconsideration of the objection under 35 U.S.C. § 132(a) for introducing new matter into the disclosure.

Regarding the amendment to claim 1, the Office action asserts that a "spatial modulation section" is new matter. Page 2, lines 23 and 24. However, the specification describes a GLV (grated light valve) driving section 43 of a control circuit 40. See e.g., page 24, line 23, to page 26, line 10, and Fig. 8. The GLV is an exemplary type of spatial modulator. See e.g., page 2, lines 1-7, page 8, lines 26-29, page 10, lines 6-9, and claim 5. Further, claim 1 has been amended to change "spatial modulation section" to "spatial modulator driving section", to more closely match the wording "GLV driving section". Because the specification discloses a control circuit 40 having a spatial modulator driving section 43, the objection to the amendment as it pertains to this portion of claim 1 is improper.

Further regarding claim 1, the Office action asserts that the claim recites, "...in association with the Fourier transformed data" and that the specification fails to "teach the 'association' with the Fourier transformed data in driving the modulation elements. Page 2, lines 23 and 24. However, claim 1 does not recite, "...in association with the Fourier transformed data", as asserted. Further, the specification describes that the GLV ribbons (i.e., the "modulator elements") are driven in accord with Fourier transfomed data. See e.g., page 10, line 19, to page 11, line 22, and page 23, lines 8-22, of the clean substitute specification. Because the specification discloses a spatial modulator driving section that controls the independent driving of modulator elements in accord with Fourier transformed data, the claim amendment did not add new matter and the objection to the amendment as it pertains to this portion of claim 1 is improper.

Regarding claim 3, the Office action asserts that the specification does not support recitation of "the second scan unit scanning the modulated light in (the) arraying direction." However, the amendment to claim 3 does not change the direction that the second scan unit scans the modulated light to. In the claim before the amendment, the claim recited in relevant part, "the second scan unit scanning the modulated light in a direction parallel to an arraying direction...", and the amended claim recites in relevant part, "the second scan unit scanning the modulated light in (the) arraying direction...". No new matter has been added because the direction being recited was previously claimed (i.e., a direction parallel to the arraying direction is the same direction as the arraying direction). Accordingly, the objection to the amendment is improper as it pertains to claim 3. Further, the Office action makes comments (page 3, lines 3-7) regarding the perceived inoperability of the claimed apparatus. Perceived inoperability is not grounds for asserting that new matter has been added.

Regarding claim 7, the Office action asserts that "scanning the modulated light in (the) first direction and in a second direction" is new matter. However, scanning light in two directions is described with respect to scanning mechanisms (e.g., galvano mirrors) 34 and 35. See e.g., Fig. 4, page 17, line 20, to page 18, line 8, and page 21, lines 11-14 of the clean substitute specification. Because the scanning mechanisms may be rotated about axes that are orthogonal to each other (see e.g., page 18, lines 1-8, and page 21, lines 11-14), they can scan light that is incident on their surfaces so the light

leaving the first mechanism is orthogonal to the light leaving the second mechanism. Again, although the Office action makes comments (see page 3, lines 3-7) regarding the perceived inoperability of the claimed apparatus, perceived inoperability is not grounds for asserting that new matter has been added. Because the amendment to the cited portion of claim 7 does not add new matter, the objection to the amendment as it pertains to this portion of claim 7 is improper.

Further regarding claim 7, the Office action asserts that the recitation, "means for receiving image data corresponding to the coherent light", is new matter. However, the specification supports this recitation in various places. For example, in lines 8-13 of page 23 of the clean substitute specification, the specification describes that the Fourier transformation section "receives image display data from an external apparatus..and performs the Fourier transformation processing of the display image data." Lines 10-16 of page 22 further state that the display image data is input into the control circuit and may be from an apparatus located outside the display apparatus. See also, Fig. 8, which shows the control circuit 40 receiving display image data. Further, in lines 15-22 of page 23, the specification describes that the GLV is controlled "in accordance with the data input from the Fourier transformation section." Because the amendment to this portion of claim 7 does not add new matter, the objection to the amendment as it pertains to this portion of claim 7 is improper.

Regarding claim 8, the Office action asserts that the recitation, "Fourier transforming image data associated with (the) light", is new matter. However, the specification supports this recitation in various places. For example, in lines 8-13 of page 23 of the clean substitute specification, the specification describes that a Fourier transformation section "receives image display data from an external apparatus..and performs the Fourier transformation processing of the display image data." Further, in lines 15-22 of page 23, the specification describes that the GLV is controlled "in accordance with the data input from the Fourier transformation section." Because the amendment to claim 8 does not add new matter, the objection to the amendment as it pertains to claim 8 is improper.

Regarding claim 13, the Office action asserts that the recitation, "scanning the modulated light to (the) first direction", is new matter. However, as described above with

respect to the objection to the amendments made to claim 7, the specification describes scanning light in two distinct directions. See e.g., Fig. 4, page 17, line 20, to page 18, line 8, and page 21, lines 11-14 of the clean substitute specification. Because the scanning mechanisms may be rotated about axes that are orthogonal to each other (see e.g., page 18, lines 1-8, and page 21, lines 11-14), the scanning mechanisms can scan light incident on their surfaces so the light leaving the first mechanism (i.e., in a first direction) is orthogonal to the light leaving the second mechanism (i.e., in a second direction).

Because the cited claim amendments do not add new matter for at least the reasons described above, the objection for adding new matter is improper. Accordingly, Applicant respectfully requests that the objection be withdrawn.

Claim Rejections - 35 U.S.C. § 112, first paragraph

Claims 1-5, 7-15, and 17

Applicant respectfully requests reconsideration of the rejection of claims 1-5, 7-15, and 17 under 35 U.S.C. §112, first paragraph, for failing to comply with the written description requirement. The objection states that the reason for the rejection is that the amendment adds new matter as described in the Section 132(a) objection. Because the amendments do not add new matter as shown above regarding the Section 132(a) objection, this Section 112 rejection is improper for the same reasons presented regarding the objection. Accordingly, Applicant respectfully requests the rejection be withdrawn.

Claims 1-5 and 8-15

Applicant respectfully requests reconsideration of the rejection of claims 1-5 and 8-15 under 35 U.S.C. §112, first paragraph, for containing subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. The Office action asserts that the feature, "Fourier transformation of image data", is not clearly taught in the specification and claims. The specification describes that the Fourier transformation is performed on a function a(x): $A(X) = H(X) \exp[i\phi(X)]$, wherein a(x) is an amplitude of the wavefront generated by the GLV in an x direction and each ribbon of the GLV is driven so that a phase difference corresponding to a phase component $\phi(X)$ is

given to the reflected light. See page 10, lines 19-28, of the clean substitute specification. Further in lines 8-13 of page 23 of the clean substitute specification, the specification describes that a Fourier transformation section "receives image display data from an external apparatus..and performs the Fourier transformation processing of the display image data." Also, in lines 15-22 of page 23, the specification describes that the GLV is controlled "in accordance with the data input from the Fourier transformation section". Applicant is not clear why the Examiner asserts that one skilled in the art would not understand how the Fourier transformation works while stating that "it is very well known in the art to apply Fourier transformation on image data in the process of processing the image data." See page 8, lines 1-5, of the Office action.

Because the specification describes the claimed subject matter in such a way as to enable one skilled in the art, the rejection is improper. Accordingly, Applicant respectfully requests the rejection be withdrawn.

Claims 1 -17 - Claim Objections

Applicant respectfully requests reconsideration of the objection of claims 1-17. As an initial matter, the bases provided for the objection are not proper for an objection. Objections are meant to address the form of a claim, such as a claim being allowable except being dependant on a rejected claim. See e.g., MPEP 706.01. Perhaps the presented bases are more appropriately presented as part of a rejection under Section 112, first paragraph. Nonetheless, Applicant addresses each basis as follows.

Regarding claim 1, the Office action asserts there is no logical relationship between the controller and the other claim elements to make the display device workable. However, the claims recite that the Fourier transformation section of the controller transforms the light radiated by the light source element and the spatial modulator driving section controls the independent driving of the elements of the spatial modulator element. Sufficient connection between the controller element and the other claim elements is present because connections between components of the controller and the other claim elements is recited. Further, additional language regarding the relationship between the controller and the other elements has been added to claim 1 (e.g., "..section connected to (the) one-dimensional spatial modulator..."). Because claim 1 and its dependant claims

recite sufficient connection between the controller and other claim elements, the objection is improper.

Further regarding claim 1, the Examiner states she does not understand what the recited "reference signal" generated by the clock is. The reference signal is a time signal that the controller references its operation to. One skilled in the art would be aware that a controller would include a clock producing a reference or time signal. The Office action further expresses confusion regarding the function of the reference signal with respect to the other apparatus elements. Claim 1 has been amended to include additional language connecting the clock to another element (i.e., "...modulator driving section ..operating at a timing based on the reference signal" and "..modulator driving section connected to..(the) clock"). Support for these amendments can be found, among other places, on page 22, line 23, to page 23, line 6, on page 23, line 15, to page 24, line 4, and in Fig. 8. Further, the specification clearly states, as will be apparent to those skilled in the art, that apparatus elements including the GLV section and galvano mirror driving section operate "at suitable timings in cooperation with each other" by operating according to the clock signal. See page 23, line 29, to page 24, line 18.

The Office action goes on to ask many questions including about how the image data that is Fourier transformed can be "associated" with the light. As described in the specification, the Fourier transformation section "receives image display data from an external apparatus..and performs the Fourier transformation processing of the display image data" and the GLV is controlled "in accordance with the data input from the Fourier transformation section". See page 23, lines 8-13 and 15-22.

In lines 1-4 of page 5, the Office action expresses confusion with respect to the claimed Fourier transformation. The Fourier transformation section and function of the invention is described above with respect to the objection regarding claims 1, 7, and 8 for containing new matter and above regarding the controller in the present objection section.

In line 4 of page 5, the Office action asks "what is the spatial modulation section?" The spatial modulation section is now referenced in the claims as the spatial modulator driving section. The spatial modulator or GLV section 43 is a component of the controller that sends signals to the spatial modulator or GLV to control elements of the spatial modulator or GLV. See e:g., lines 16-18 of page 22 and lines 15-22 of page 23.

Further, Applicant is not clear why the Examiner asserts confusion regarding how the controller could accept image data and thereby drive the elements of the GLV while citing a reference (Bloom) that discloses a control circuitry 440 that accepts video data and is coupled to the GLV 402 for using the video data to operate the GLV elements 200 for modulating light diffracted therefrom and while citing a reference (Kajiki) that discloses modulating light based on stereoscopic video image data received by way of a transmission line. See Bloom, column 10, lines 43-47, and Kajiki, column 11, lines 12-15.

In line 4 of page 5, the Office action expresses confusion regarding whether the spatial modulation section modulates. Actually, the spatial modulator or GLV (e.g., item 32 in Fig. 4) modulates the light. See e.g., lines 4-8 of page 17.

In lines 4 and 5 of page 5, the Office action expresses confusion regarding the modulation elements and how they relate to the spatial modulator. The modulation elements or ribbons, such as items 11 in Figs. 1 and 2 and items 32a, 32b, and 32c in Fig. 4, are distributed across the surface of the spatial modulator (e.g., GLV 10 or 32). The modulation elements 11, 32a-c independently ascend and descend to modulate or alter the relative spacing of the light diffracted from the spatial modulator. See e.g., Figs. 1 and 2, page 10, lines 6-17, and page 11, lines 9-13.

In lines 5 and 6 of page 5, the Office action expresses confusion regarding how the transformed image data relates to the rest of the elements of the apparatus. As recited in claim 1, the spatial modulator driving section of the controller controls the independent driving of the modulator elements in accord with the transformed data. As described above and in the specification, the transformation is performed on the image data corresponding to the radiated light to determine the relative amounts the modulator elements should be ascended/descended to produce desired display characteristics. See e.g., page 10, lines 6-28.

In lines 6-8 of page 5, the Office action asserts that without the controller, the apparatus only discloses scanning the light back and forth. Applicant is not clear why the Examiner is analyzing what the claim would disclose if parts of the claim were removed. Because elements of the controller are recited and related to other apparatus elements, the controller elements must be considered.

In subsection (2) on page 5, the Office action expresses confusion regarding the "scan unit axis" with respect to the scanning directions. The scan unit axes are the axes about which the scanning units (e.g., 34 and 35 in Fig. 4) rotate. See e.g., page 18, lines 1-8, and Fig. 4. The scanning directions are the directions in which the light travels after being scanned by the scanning units. For example, the first scanning unit or galvano mirror 34 can rotate about a z-axis to scan light in a horizontal direction and the second scanning or galvano mirror 35 can rotate about an x-axis to scan light in a vertical direction. See e.g., page 18, lines 1-19, and Fig. 4.

In subsection (3) on page 5, the Office action expresses confusion regarding the "Fourier surface" recited in claim 6. The Fourier surface is not "any surface ... downstream of the Fourier transformation lens," as stated by the Examiner because, as recited in the claim and described in the specification, the Fourier transformation surface is part of the Fourier transformation lens and the diffuser panel *is disposed on* (i.e., in contact with) the Fourier surface. See e.g., page 21, line 14, to page 22, line 8.

In subsection (4) on page 5, the Office action expresses confusion regarding the phrase, "means for receiving image data corresponding to the coherent light", recited in claim 7. The image data and means for receiving have been described above. For example, in lines 8-13 of page 23 of the clean substitute specification, the specification describes that the Fourier transformation section "receives image display data from an external apparatus..and performs the Fourier transformation processing of the display image data." Lines 10-16 of page 22 further states that the display image data is input into the control circuit and may be from an apparatus located outside the display apparatus. Also note Fig. 8, which shows the control circuit 40 receiving display image data. Further, in lines 15-22 of page 23, the specification describes that the GLV is controlled "in accordance with the data input from the Fourier transformation section". The Office action also specifically states that it appears the "means for receiving image data" has no relation to the other elements. However, it is clear from the claim and specification that the means for receiving image data receives the data used by the means for spatially modulating the light, which is controlled in part according to Fourier transformation of the image data. See e.g., claim 7, page 22, lines 10-16, page 23, lines 8-13, page 23, lines 15-22, and Fig. 8.

In subsection (5) on pages 5 and 6, the Office action expresses confusion regarding the phrase "Fourier transforming image data associate with light". The Office action states that the Image data is not associated with light. However, the specification describes that the display image data is associated with the stereoscopic images to be displayed, which are formed by altering the incident light (see e.g., Fig. 1). See page 22, lines 12-15. The Office action further states there is no connection between the transformed image data and the rest of the image display. However, as stated above, the specification describes that the Fourier transformation section "receives image display data from an external apparatus...and performs the Fourier transformation processing of the display image data." Lines 10-16 of page 22 further state that the display image data is input into the control circuit and may be from an apparatus located outside the display apparatus. Also note Fig. 8, which shows the control circuit 40 receiving display image data. Further, in lines 15-22 of page 23, the specification describes that the GLV is controlled "in accordance with the data input from the Fourier transformation section".

In subsection (5), the Office action also states that it appears the "means for receiving Image data" has no relation to the other elements. It is clear from the claim and specification that the means for receiving image data receives the data used by the means for spatially modulating the light, which is controlled in part according to Fourier transformation of the image data. See e.g., claim 7, page 22, lines 10-16, page 23, lines 8-13, page 23, lines 15-22, and Fig. 8. The modulation elements or ribbons, such as items 11 in Figs. 1 and 2 or items 32a, 32b, and 32c in Fig. 4, are driven to independently ascend/descend to modulate or alter the relative spacing of the light diffracted from the spatial modulator. See e.g., Figs. 1 and 2, page 10, lines 6-17, and page 11, lines 9-13. As described in the specification, modulation of the light is part of creating desired display images.

In subsection (6) on page 6, the Office action expresses confusion regarding how the scan unit recited in claim 9. Claim 9 has been amended to depend from claim 2, which states the scan unit scans the light in two directions. The amendment overcomes the objection.

For the reasons described above, Applicant respectfully requests withdrawal of the objection to claims 1-17.

Claims 1 and 5 – 35 U.S.C. § 103

Applicant respectfully requests reconsideration of the rejection of claims 1 and 5 under 35 U.S.C. § 103(a) as being unpatentable over the patent issued to U.S. Patent No. 6,215,579 (Bloom) in view of the patent issued to U.S. Patent No. 6,043,652 (Liu). As amended, claims 1 and 5 recite a controller including a clock for generating a reference signal by which the controller operates, a Fourier transformation section that performs Fourier transformation of image data associated with the light during operation of the apparatus and a spatial modulator driving section connected to the clock and connected to the one-dimensional spatial modulator, wherein the driving section operates at a timing based on the reference signal, and controls the independent driving of modulator elements in accordance with the Fourier transformed data.

Bloom discloses an apparatus and method for modulating light including deforming elongated elements 200 by varying a drive voltage. Liu discloses a method for reconstructing data including Fourier transforming data lines, storing the transformed data lines in memory, and converting the transformed data lines into an appropriate format for display. See column 9, lines 41-51. Although Bloom discloses modulating light and Liu discloses Fourier transforming data, the references, individually and in combination, fail to disclose controlling independent driving of modulator elements in accordance with Fourier transformed data. Specifically, Liu discloses storing the transformed data and converting the data to a format for display (column 9, lines 41-51) but does not show or suggest using the stored transformed data to control a modulator. Bloom discloses a modulator 402 and controlling the modulator by varying a drive voltage using a control circuitry 440 (column 10, lines 43-47), but fails to show or suggest controlling the drive voltage using Fourier transformed data.

The Office action states the claim does not include a logical relationship between the controller and the other apparatus elements. Page 7, lines 13-15. However, logical relationships between the controller were present in the claim and the claim has been amended to include language providing additional bases for the relationships as described above regarding the objection to claim 1.

Because Bloom and Liu, individually and in combination, fail to show or suggest every feature of the claims, the rejection is improper. Accordingly, Applicant requests the rejection be withdrawn.

Claims 7, 8, 13, and 14 – 35 U.S.C. § 103

Applicant respectfully requests reconsideration of the rejection of claims 7, 8, 13, and 14 under 35 U.S.C. § 103(a) as being unpatentable over the patent issued to U.S. Patent No. 5,694,235 (Kajiki) in view of the patent issued to Liu. Claim 7 recites an image display apparatus comprising means for radiating coherent light, means for receiving image data corresponding to the coherent light, means for spatially modulating the coherent light in a first direction, wherein the means for spatially modulating is controlled in part according to Fourier transformation of the image data, and means for scanning the modulated light in the first direction and in a second direction that is orthogonal to the first direction. Claim 8 recites an image display method comprising radiating coherent light, Fourier transforming image data associated with the light, spatially modulating the coherent light in a first direction in accord with the transformed image data, and scanning the modulated light to a second direction that is orthogonal to the first direction at a first speed.

Kajiki discloses a 3-D recording/reproducing system including a modulator 19. Liu discloses a method for reconstructing data including Fourier transforming data lines, storing the transformed data lines in memory, and converting the transformed data lines into an appropriate format for display. See column 9, lines 41-51. Although Kajiki discloses modulating light and Liu discloses Fourier transforming data, the references, individually and in combination, fail to disclose controlling a modulator in accord with Fourier transformed data. Specifically, Liu discloses storing the transformed data and converting the data to a format for display (column 9, lines 41-51), but does not show or suggest using the stored transformed data to control a modulator. Kajiki discloses modulating light in response to video image data (column 11, lines 12-15), but fails to show or suggest controlling the drive voltage using Fourier transformed data.

The Office action asserts the specification does not support the claim 7 feature, "means for receiving image data corresponding to the coherent light." However, the specification supports this feature as described above regarding the objection to the

amendments and regarding the objection with respect to claim 7 made in subsection (4) of the Office action.

The Office action also asserts the specification does not support the claim 8 feature, "Fourier transforming image data associated with light." However, the specification supports this feature as described above regarding the objection to the amendments and regarding the claim objections.

In addition, the Office action asserts the phrase, "modulating is controlled in part according to a Fourier transformation of image data" is indefinite. However, the claim language is definite, as described above regarding the 35 U.S.C. §112, first paragraph, rejection of claims 1-5 and 8-17.

Further regarding claim 13, the references, individually and in combination, fail to show or suggest, "spatial modulation...controlled based on an amount of shifting of the scanned light resulting from (the) differing scanning speeds."

Further regarding claim 14, the references, individually and in combination, fail to show or suggest the modulation device rotating during performance of the method. The Office action expresses confusion as to whether the rotation of the modulator achieves the scanning function and asserts it would have been obvious to rotate the modulator to achieve the scanning function to eliminate the need for the scanners. The rotating modulation device performs scanning. See e.g., page 26, lines 14-17. However, it would not have been obvious to rotate the modulator of Kajiki and a *prima facie* case of obviousness has not been made. The first criteria for a *prima facie* case of obviousness is "there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings." MPEP 2143. The only motivation provided in the Office action is that rotating the modulator would eliminate the need for scanners. However, Kajiki clearly discloses the need for scanners and makes no suggestion of not using them. The MPEP requires the Examiner to carefully guard against the natural tendency to resort to hindsight. See MPEP 2142. The references do not show or suggest rotating a modulator as claimed. If it were indeed simpler, cheaper, etc., and obvious to rotate the modulator, the feature would have been taught before the present invention.

Because the Kajiki and Liu, individually and in combination, fail to show or suggest every feature of the claims, the rejection is improper. Accordingly, Applicant requests the rejection be withdrawn.

Claims 1-5, 11, and 12 – 35 U.S.C. § 103

Applicant respectfully requests reconsideration of the rejection of claims 1-5, 11 and 12 under 35 U.S.C. § 103(a) as being unpatentable over Kajiki, in view of Bloom, and further in view of U.S. Patent No. 6,043,652 (Liu). As amended, claims 1-5, 11, and 12 recite a controller including a clock for generating a reference signal by which the controller operates, a Fourier transformation section that performs Fourier transformation of image data associated with the light during operation of the apparatus and a spatial modulator driving section connected to the clock and connected to the one-dimensional spatial modulator, wherein the driving section operates at a timing based on the reference signal, and controls the independent driving of modulator elements in accordance with the Fourier transformed data.

Kajiki discloses a 3-D recording/reproducing system including a modulator 19. Bloom discloses an apparatus and method for modulating light including deforming elongated elements 200 by varying a drive voltage. Liu discloses a method for reconstructing data including Fourier transforming data lines, storing the transformed data lines in memory, and converting the transformed data lines into an appropriate format for display. See column 9, lines 41-51. Although Kajiki and Bloom disclose modulating light and Liu discloses Fourier transforming data, the references, individually and in combination, fail to disclose controlling independent driving of modulator elements in accordance with Fourier transformed data. Specifically, Kajiki discloses modulating light in response to video image data (column 11, lines 12-15), but fails to show or suggest controlling the drive voltage using Fourier transformed data. Bloom discloses a modulator 402 and controlling the modulator by varying a drive voltage using a control circuitry 440 (column 10, lines 43-47), but fails to show or suggest controlling the drive voltage using Fourier transformed data. Liu discloses storing the transformed data and converting the data to a format for display (column 9, lines 41-51) but does not show or suggest using the stored transformed data to control a modulator.

The Office action states the claim does not include a logical relationship between the controller and the other apparatus elements. However, logical relationships between the controller were present in the claim and the claim has been amended to include language providing additional bases for the relationships as described above regarding the objection to claim 1.

Because Kajiki, Bloom and Liu, individually and in combination, fail to show or suggest every feature of the claims, the rejection is improper. Accordingly, Applicant requests the rejection be withdrawn.

Claims 9, 10, and 15 – 35 U.S.C. § 103

Applicant respectfully requests reconsideration of the rejection of claims 9, 10, and 15 under 35 U.S.C. § 103(a) as being unpatentable over Kajiki, Bloom, and Liu, and further in view of U.S. Patent No. 5,550,779 (Burr). Because claims 9, 10, and 15 depend from claim 1, the rejection of claims 9, 10, and 15 is improper for the same reasons presented above regarding the rejections of claim 1. Accordingly, Applicant requests the rejection be withdrawn.

Claim 6 – 35 U.S.C. § 103

Applicant respectfully requests reconsideration of the rejection of claim 6 under 35 U.S.C. § 103(a) as being unpatentable over Kajiki in view of Bloom. Claim 6 discloses, among other things, an image display apparatus including a collimator lens making the light modulated by the Grating Light Valve device into parallel rays, a scan unit scanning the parallel rays coming from the collimator lens, a Fourier transformation lens having a Fourier surface and performing Fourier transformation on the scanned rays, and a diffuser panel disposed on the Fourier surface for diffusing the rays coming from the Fourier lens.

Kajiki discloses a 3-D recording/reproducing system including a modulator 19. Bloom discloses an apparatus and method for modulating light including deforming elongated elements 200 by varying a drive voltage. Kajiki and Bloom, individually and in combination, fail to show or suggest an image display apparatus including a collimator lens making the light modulated by the Grating Light Valve device into parallel rays, a scan unit

scanning the parallel rays coming from the collimator lens, a Fourier transformation lens having a Fourier surface and performing Fourier transformation on the scanned rays, and a diffuser panel disposed on the Fourier surface for diffusing the rays coming from the Fourier lens. Particularly, the Office action asserts that the lens 22 or 14a, 14b of Kajiki collimate light from the modulator. However, as is clear from Figs. 11 and 13, these lenses 22, 14a/14b only collimate light leaving the light source 18 with no intervening structures such as a modulator. Further, the Office action asserts that the lens 2 of Kajiki Fourier transforms modulated light. However, Kajiki makes no mention or suggestion of a Fourier lens or Fourier transforming light. In addition, the diffusion plate 20 of Kajiki is not *disposed on* a surface of a Fourier transformation lens, as claimed. The Examiner's confusion regarding the location of the diffusion panel of the present invention with respect to the Fourier lens was addressed above regarding the objection to claim 6 in subsection (3) of the claim objections.

Because the references, individually and in combination, fail to show or suggest every feature of the claim, the rejection is improper. Accordingly, Applicant requests the rejection be withdrawn.

<u>Claim 16 – 35 U.S.C. § 103</u>

Applicant respectfully requests reconsideration of the rejection of claim 16 under 35 U.S.C. § 103(a) as being unpatentable over Kajiki and Bloom as applied to claim 6 above, and further in view of Burr. Because claim 16 depends from claim 6, the rejection of claim 16 is improper for the same reasons presented above regarding the rejection of claim 6. Accordingly, Applicant requests the rejection be withdrawn.

<u>Claim 17 – 35 U.S.C. § 103</u>

Applicant respectfully requests reconsideration of the rejection of claim 17 under 35 U.S.C. § 103(a) as being unpatentable over Kajiki, and Liu as applied to claim 7 above, and further in view of Burr. Because claim 17 depends from claim 7, the rejection of claim 17 is improper for the same reasons presented above regarding the rejection of claim 7. Accordingly, Applicant requests the rejection be withdrawn.

Conclusion

As it is believed that the Application is in condition for allowance, a favorable action and Notice of Allowance are respectfully requested.

Respectfully submitted,

Date: 2/8/6

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Marked Substitute Specification

STEREOSCOPIC IMAGE DISPLAY APPARATUS

RELATED APPLICATION DATA

This application claims priority to Japanese Patent Application JP 2000-358207, and the disclosure of that application is incorporated herein by reference to the extent permitted by law.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a stereoscopic image display apparatus for displaying a stereoscopic image.

2. Description of the Related Art

Various kinds of display apparatus for displaying planar images (two-dimensional images) by radiating light have hitherto been put to practical use. For example, a liquid crystal panel and a digital micro-mirror device (DMD) have been used as a spatial modulator for modulating light to be projected according to a planar image to be displayed in such a display apparatus.

Moreover, research and development of diffraction gratings that can freely be driven by micro-machines have been proceeding in recent years. Bloom et al (U.S. Pat. No. 5,311,360) discloses a display apparatus using such a diffraction grating as a spatial modulator for modulating light to be projected ~~according to a displaying image was submitted and has been widely noticed~~.

~~The~~ A micro-machine type diffraction grating ~~to be~~ used as a spatial modulator ~~like this~~ is generally called ~~as~~ a Grating Light Valve (GLV)[[,]]. GLVs have ~~and such a diffraction grating has~~ features ~~such that it can~~ allowing them to be operated at a higher speed and can be manufactured at a lower cost by using various ~~kinds of~~ semiconductor manufacturing techniques ~~in comparison with a~~ compared to liquid crystal ~~panel~~ panels and ~~a DMD~~ DMDs that have hitherto been used as a spatial modulator.

Accordingly, it is expected that a display apparatus can display a clear and bright image without any discontinuity and can be realized at a low cost when the display apparatus is configured by the use of the GLV.

On the other hand, as for display apparatuses for displaying stereoscopic images (three-dimensional images), though the display apparatuses have hitherto been realized by the use of various systems, many of them have various restrictions such that visual fields are limited within narrow ranges or that special glasses are needed to see, and they have not been put to full-scale practical use yet.

Accordingly, various technologies making it possible to display stereoscopic images in real time by the use of various hologram techniques have been proposed in recent years. As an example of such proposals, there is a display apparatus (U.S. Pat. No. 5,172,251) that uses acousto-optic

devices controlled by a computer apparatus or the like as one-dimensional hologram devices (hereafter called computer generated hologram (CGH)) and displays stereoscopic images by scanning one-dimensional stereoscopic images generated by the CGH in horizontal directions and vertical directions.

SUMMARY OF THE INVENTION

~~However, in the case where~~ Where stereoscopic images are displayed by the use of ~~the~~ acousto-optic devices in the way described above, for example, the acousto-optic devices are used as one-dimensional hologram devices by creating a refractive index distribution by the input of ultrasonic waves according to displaying images. However, the displayed images may be distorted as if the displayed image is flowing due to the nature of the ultrasonic waves to be traveling waves. Accordingly, it is necessary to correct the "flowing" distortion of displayed images by the use of, for example, a polygon mirror or a galvano-mirror. In this case, ~~there are~~ problems presented include ~~such that~~ the whole structure of the display apparatus ~~becomes~~ being complicated[[,]] and ~~further that it is needed~~ the need to adjust the timing of the correction to be extremely accurate lest time lags ~~should~~ will be generated.

Moreover, devices other than the acousto-optic devices are ~~so far~~ difficult to ~~obtain~~ use as a spatial modulator that can operate at a high speed and perform ~~the modulation~~ modulation with an abundant amount of information~~, both the speed and the amount being sufficient~~ to display stereoscopic

images~~, in a display apparatus for displaying the stereoscopic images~~. ~~The~~ Further, conventional acousto-optic devices ~~have shortcomings of that they~~ are expensive and ~~that~~ high voltages are necessary ~~for driving~~ to drive them.

~~There is another problem. Enormous~~ An enormous amount of information is required for displaying stereoscopic images because it ~~becomes~~ is necessary to display precise information in three-dimensional directions. It is not practical ~~at present~~ to control such enormous amount of information with conventional devices. Moreover, because the amount of information to display a stereoscopic image increases by leaps and bounds as the sizes of the images to be displayed become large, display of a large size stereoscopic images becomes very difficult. ~~Besides~~ Also, in the case where stereoscopic images are displayed as moving picture in real time, the necessary amount of information further jumps up by leaps and bounds[[,]] and it ~~becomes~~ is necessary to process an enormous amount of information at extremely high speed.

Although various kinds of display apparatuses for displaying stereoscopic images have hitherto been proposed, such display apparatuses have many problems, such as those mentioned above, and ~~the display apparatuses~~ are not put to practical use yet.

The present invention is made in consideration of the

aforesaid situation and problems. It is desired to provide a stereoscopic image display apparatus capable of displaying stereoscopic images at a higher speed and with a simpler structure than can be manufactured at a lower cost.

According to ~~an~~ one embodiment of the present invention, a ~~stereoscopic image display apparatus is provided. The~~ stereoscopic image display apparatus comprises a light source radiating light of a wavelength in a predetermined wavelength range~~; an~~, a one-dimensional spatial modulator including one-dimensionally arrayed elements that are independently driven to generate an arbitrary phase distribution[[;]], and a scan unit scanning the light from the light source to a predetermined direction, the light having entered into the one-dimensional spatial modulator and having been modulated therein.

The stereoscopic image display apparatus according to the present embodiment~~, which configured as above,~~ uses the one-dimensional spatial modulator including the independently driven elements as a spatial modulator for modulating light to be projected. Because such a one-dimensional spatial modulator may be operated at ~~a~~ an extremely high speed, stereoscopic images may be displayed based on a sufficiently abundant amount of information. Moreover, because the stereoscopic image display apparatus displays stereoscopic images by the use of light modulated by the one-dimensional spatial modulator, the overall structure of the apparatus may be simplified, and the

manufacturing cost thereof may be lowered. Moreover, the apparatus may express a stereoscopic effect without any special equipment such as special glasses to view stereoscopic image.

Moreover, the stereoscopic image display apparatus of the present embodiment displays stereoscopic images by scanning and radiating the light modulated by the one-dimensional spatial modulator. Thereby, for example, the stereoscopic images may be displayed with only horizontal parallax of the stereoscopic images to be displayed by the renunciation of vertical parallax. By displaying of the stereoscopic images with one directional parallax in such a way, the increase of a necessary amount of information may be suppressed, and an amount of information and a processing time, both necessary for displaying stereoscopic images, may be decreased to a practical level.

Even when the stereoscopic images are displayed with only horizontal parallax as described above, stereoscopic effects may fully be expressed because two human eyes are arrayed in a horizontal direction and more insensitive to vertical parallax than horizontal parallax.

In the stereoscopic image display apparatus according to the present embodiment, the scan unit may scan the light modulated by the one-dimensional spatial modulator in a direction perpendicular to the arraying direction of the elements of the one-dimensional spatial modulator.

Accordingly, a larger ~~size of the~~ stereoscopic image may be displayed and a wider viewing field may be ensured ~~by projecting the scanning light that is modulated with the one-dimensional spatial modulator and scanned with the scan unit into the perpendicular direction to the arraying direction of the elements since~~ because the one-dimensional spatial modulator with the individually driven elements may be operated in a sufficiently fast speed.

According to another embodiment of the present invention, there is provided a stereoscopic image display apparatus comprising: a light source radiating light of a wavelength in a predetermined wavelength range; a Grating Light Valve device that can independently drive each ribbon-like element to generate an arbitrary phase distribution of the light; a collimator lens making the light modulated by the Grating Light Valve device into parallel ray; a scan unit scanning the parallel ray from the collimator lens; a lens performing Fourier transformation on the scanned ray; and a diffuser panel diffusing the ray Fourier transformed by the lens.

According to the above mentioned embodiment of the present invention, the stereoscopic image display apparatus capable of displaying stereoscopic images ~~in~~ at a higher speed may be realized at a lower cost with a simpler structure. Moreover, according to the above mentioned embodiment, an amount of information and a processing time, both being necessary for displaying a stereoscopic image, may be

decreased thereby enabling the moving picture display of stereoscopic images in real time.

BRIEF DESCRIPTION OF THE DRAWINGS

The other objects, features, and advantages of the present invention will become more apparent from the following description including ~~of the presently preferred~~ exemplary embodiments of the invention ~~taken~~ in conjunction with the accompanying drawings, in which:

Fig. 1 is a ~~mimetic diagram~~ schematic showing ~~a state such that light enters into a GLV being an example of~~ incident light waves approaching the GVL of a spatial modulator of the present invention;

Fig. 2 is a ~~mimetic diagram~~ schematic showing light waves ~~a state such that the light entered into~~ after being modulated by the GLV ~~being an example~~ of the spatial modulator of the present invention ~~is modulated and reflected~~;

Fig. 3 is a ~~mimetic diagram~~ schematic perspective ~~for explaining the principle of the present invention by~~ illustrating the scanning of the light modulated by the GLV ~~in a predetermined direction~~;

Fig. 4 is a schematic ~~diagram of a display apparatus shown as an example of the structure~~ perspective of the stereoscopic image display apparatus according to the present invention;

Fig. 5 is a schematic ~~diagram for illustrating the rotation directions of a first and a second galvano mirrors of the display apparatus~~ of the stereoscopic image display apparatus shown in Fig. 4 from another perspective;

Fig. 6 is a ~~mimetic diagram~~ schematic showing an example of ~~a state such that~~ scanning directions of the laser beams ~~modulated to one-dimensional wavefronts scan~~ in a projection plane on which stereoscopic images are projected by ~~in~~ the display apparatus;

Fig. 7 is a ~~mimetic diagram~~ schematic showing another example ~~of a state such that~~ scanning directions of the laser beams ~~modulated to one-dimensional wavefronts scan~~ in a projection plane on which stereoscopic images are projected by ~~in~~ the display apparatus;

Fig. 8 is a ~~schematic~~ block diagram showing a control circuit provided in the display apparatus; and

Fig. 9 is a schematic perspective ~~view~~ of ~~a mirror array shown as an example of~~ a display apparatus having a scan mechanism including a mirror arra ~~provided in the display apparatus~~.

DETAILED DESCRIPTION OF THE ~~PREFERRED EMBODIMENTS~~ INVENTION

Hereinafter, the attached drawings are referred to while ~~a preferred embodiment~~ embodiments of the stereoscopic image display apparatus according to the present invention are described~~ in detail~~.

One of the features of a first embodiment of the present ~~embodiment~~ invention is to use a micro-machine type one-dimensional spatial modulator as a spatial modulator for modulating light to be projected. Specifically, as such a spatial modulator, a micro-machine type diffraction grating may be used. The micro-machine type diffraction grating is

generally called as a Grating Light Valve (GLV) when ~~it is~~ used as a spatial modulator.

~~The principle employed in the present embodiment is described in the following before the embodiment of the present invention is described.~~

A GLV comprises a plurality of minute ribbons formed on a substrate. The ribbons may be fabricated with various semiconductor manufacturing techniques. Each ribbon is configured to be able to ~~arbitrary~~ arbitrarily ascend and descend ~~by~~ in response to actuation from a piezoelectric device or the like. The GLV with such ribbon structure may be operated to dynamically drive each ribbon to vary its height while light with a predetermined wavelength range is irradiated thereto, thereby constituting a phase type diffraction grating as a whole. That is, the GLV generates the $\pm 1^{st}$ order (or higher order) diffracted light ~~by receiving irradiation of the light~~ from the incident irradiant light received.

Accordingly, an image may be displayed by the following operations: irradiation of light to the GLV; shielding of the 0^{th} order diffracted light; and driving each ribbon of the GLV ~~upwardly~~ upward and ~~downwardly~~ downward so as to have the diffracted light blink.

Various display apparatuses for displaying planar images (two-dimensional images) by utilizing the aforesaid

characteristics of a GLV have hitherto been ~~intoroduced~~ introduced. When a conventional display apparatus displays a constituent unit (hereinafter referred to as a pixel) of a planar image to be displayed, about six ribbons are used for displaying ~~one~~ the pixel. Furthermore, in a group of ribbons corresponding to one pixel, ~~adjoining~~ adjacent ribbons are made to ascend or descend ~~alternately~~.

However, if each ribbon in a GLV ~~may~~ is independently ~~be~~ wired to be driven separately, an arbitrary one-dimensional phase distribution may be generated. The GLV structured in such a way may be regarded as a reflection type one-dimensional phase type hologram.

In the present embodiment, the GLV structured as a reflection type one-dimensional phase type hologram in the aforesaid way is used as the micromachine type one-dimensional spatial modulator. That is, for example, as shown in Fig. 1, an arbitrary phase distribution has been generated in advance by the independent driving of each ribbon 11 of a GLV 10. When light with a predetermined wavelength range the phase of which is aligned enters into the GLV 10 from the direction indicated by an arrow in Fig. 1, the incident light is modulated and reflected. Then, as shown in Fig. 2, an arbitrary one-dimensional wavefront may be formed.

~~Hereupon, a specific example in the case where stereoscopic images are displayed by the use of such GLV is~~

~~described.~~ In the case where a stereoscopic image is displayed by the use of the GLV in which a plurality of ribbons are one-dimensionally arrayed, each ribbon of the GLV is driven as follows: the Fourier transformation of a function ~~a(x): A(X) = H(X)exp[iö(X)]~~ a(x): A(X) = H(X)exp[iφ(X)] is calculated when an amplitude of the one-dimensional wavefront generated by the GLV is expressed by the a(x) as a function in an x-direction[[;]] and then each ribbon of the GLV is driven in such a way that a phase difference corresponding to the phase component ~~ö(X)~~ φ(X) is given to the reflected light.

In order to be more precise, it is desirable to modulate the amplitude component H(X) as well. Accordingly, a more accurate three-dimensional display may be realized. Incidentally, the display apparatus may still be able to display a stereoscopic image with sufficient stereoscopic effects even if the amplitude component H(X) is set to be constant.

When the ribbon in the GLV descends by a depth [[Ø]] Ψ from its default position, a change of ~~2Ø~~ 2Ψ is generated in the optical path length for the reflected light. Accordingly, the phase difference generated by this change is ~~4ðØ/ë~~ 4πΨ/λ where [[ë]] λ designates the wavelength of the light.

Because ~~the~~ analog modulation of the GLV is possible, a desired phase difference may be given to the reflection

light by precise analog driving of the GLV. However, when a display apparatus ~~is structured by the use of~~ has such a GLV, it is practical to use a discrete calculation method such as the fast Fourier transformation. Accordingly, it is practical to discretely drive each ribbon of the GLV based on a digital signal ~~discretely, and~~ thereby ~~enabling~~ easily allowing for various ~~kinds~~ types of signal processing~~easy~~.

Another embodiment in accordance with the present invention is characterized by displaying stereoscopic images by the use of, for example, a technique shown in Fig. 3 on the basis of the aforesaid principle. As shown in Fig. 3, a GLV 20 in which a plurality of ribbons are one-dimensionally arrayed generates one one-dimensional wavefront after another. The generated wavefronts are scanned in a vertical direction by a scan mechanism comprising, for example, a galvano-mirror 21. That is, by rotating the galvano-mirror 21 in a direction shown by an arrow A in Fig. 3, a plurality of wavefronts 22a, 22b, 22c are radiated in such a way that they are arranged in the vertical direction. Thereby, a stereoscopic image may be displayed. It is desirable to provide a one-dimensional diffuser panel 23 in the vicinity of the stereoscopic image to be displayed. By the diffuser panel 23, a vertical visual field may be enlarged slightly, and discontinuities between the wavefronts 22a, 22b, 22c are made to be inconspicuous. Accordingly, more natural stereoscopic effects may be expressed. Although horizontal parallax may be sufficiently achieved by the technique shown in Fig. 3, it is difficult to also obtain vertical parallax.

This difficulty is addressed in the following.

~~That is, as shown in Fig. 3, a GLV 20 in which a plurality of ribbons are one-dimensionally arrayed generates an one-dimensional wavefront one after another. The generated wavefronts are scanned in a vertical direction by a scan mechanism comprising, for example, a galvano mirror 21. That is, by the rotation of the galvano mirror 21 in a direction shown by an arrow A in Fig. 3, a plurality of wavefronts 22a, 22b, 22c are radiated in such a way that they are arranged in the vertical direction. Thereby, a stereoscopic image may be displayed.~~

~~As shown in Fig. 3, it is desirable to provide an one-dimensional diffuser panel 23 in the vicinity of a stereoscopic image to be displayed. By the diffuser panel 23, a vertical visual field may be enlarged slightly, and discontinuities between the wavefronts 22a, 22b, 22c are made to be inconspicuous. Accordingly, more natural stereoscopic effects may be expressed.~~

~~Now, in the case where stereoscopic images are displayed by the vertical scanning of one-dimensional wavefronts with utilizing the technique shown in Fig. 3, horizontal parallax may sufficiently be secured, but it becomes difficult to obtain vertical parallax as well. Accordingly, such difficulty is addressed in the following.~~

When a display apparatus ~~is structured by the use of~~

includes a diffraction grating such as a GLV or a hologram, the relations expressed by the following Equation 1 and Equation 2 are satisfied, where the maximum spatial frequency of the diffraction grating, the shortest period of the grating, a reproduced wavelength, and a diffraction angle (the diffraction angle influences the extent of a visual field) are respectively designated by f_h, [[Ë]]$\underline{\Lambda}$, [[ë]]$\underline{\lambda}$, and [[è]]$\underline{\theta}$.

~~Fh = 1/Ë~~ $\underline{f_h = 1/\Lambda}$ ... (Equation 1)

~~Fë = sinè~~ $\underline{f_h\lambda = \sin\theta}$ ... (Equation 2)

According to the sampling theorem, the minimum sampling frequency f_s may be expressed ~~to meet to~~ by the following Equation 3.

$f_s = 2f_h$ ... (Equation 3)

Accordingly, a sample number N necessary for reproducing ~~an~~ a one-dimensional stereoscopic image having a horizontal length d may be expressed ~~to meet~~ by the following Equation 4.

~~N = d·fs = (2d·sinè)/ë~~ $\underline{N = d \cdot f_s = (2d \cdot \sin\theta)/\lambda}$ ... (Equation 4)

Moreover, when the vertical resolution of the display apparatus is designated by L, the total number N_h of the samples constituting one stereoscopic image may be expressed by the following Equation 5 in the case where the stereoscopic

image is displayed by the technique shown in Fig. 3, namely when L pieces of the one-dimensional type diffraction gratings are vertically arranged.

$\cancel{N_h = dL\cdot f_s = (2dL\cdot\sin\theta)/\lambda}$ $N_h = dL\cdot f_s = (2dL\cdot\sin\theta)/\lambda$ ... (Equation 5)

In order to secure the vertical parallax, a total number N_{hv} of the samples necessary for constituting one stereoscopic image may be expressed by the following Equation 6 where the vertical length of the stereoscopic image is designated by w.

$\cancel{N_{hv} = (2dw\cdot\sin^2\theta)/\lambda^2}$ $N_{hv} = (2dw\cdot\sin^2\theta)/\lambda^2$ ... (Equation 6)

As ~~being apparent~~ can be seen by ~~the comparison of~~ comparing Equation 5 and Equation 6, a required amount of information (the number of samples) remarkably increases when achievement of both ~~the~~ horizontal ~~parallax~~ and ~~the~~ vertical parallax are ~~tried to be~~ secured, compared to when ~~in comparison with that in the case where~~ only ~~the~~ horizontal parallax is secured. For example, when the diffraction angle θ is 30 degrees and the reproduced wavelength λ is 0.5 μm, the total number N_{hv} of required samples is 2dw x 10^{12} according to Equation 6. Further, when the horizontal length d and vertical length w of a stereoscopic image to be displayed are 100 mm, the total number N_{hv} of samples necessary for displaying one stereoscopic image is 2 x 10^{10}. That is, 20

G bits (gigabits) of information becomes necessary to display a single stereoscopic image. Moreover, for example, if 30 stereoscopic images are to be displayed every second for displaying moving picture images, 600 G bits (75 G bytes) of information becomes necessary every second.

~~More specifically, when the diffraction angle θ is set to be 30 degrees and the reproduced wavelength λ is set to be 0.5 μm, the total number $N_{h,v}$ of the required samples is $2dw \times 10^{12}$ in conformity with Equation 6. Hereupon, when the horizontal length d and the vertical length w of a stereoscopic image to be displayed are severally set to be 100 mm, the total number $N_{h,v}$ of the samples necessary for displaying one stereoscopic image is 2×10^{10}. That is, the amount of information of 20 G bits becomes necessary for displaying one piece of stereoscopic image. Moreover, if 30 stereoscopic images are to be displayed every second for displaying moving picture image, the amount of information of 600 G bits (75 G bytes) becomes necessary every second.~~

Incidentally, ~~the amount of information of~~ 600 G bits of information is ~~equal to an~~ the same amount of information required when the moving ~~picture image is~~ pictures are displayed ~~with~~ using monochromatic and no-gradation images. If a color display with the three primary colors is ~~to be performed~~ desired, ~~an~~ the amount of information required is tripled. If eight levels of gradation ~~is~~ are to be used, eight times ~~of~~ the amount of information is ~~further~~ required. Furthermore, if displaying is performed on a 12-inch ~~size~~

display apparatus, ~~an amount of information~~ seven times the amount of information or more is further needed. ~~Accordingly, signal~~ Signal processing dealing with such an enormous amount of information at a high speed is far from being put to practical use ~~at present~~ by conventional methods.

~~On the other hand, according~~ According to the present ~~embodiment~~ invention, ~~by the use of~~ using the technique shown in Fig. 3, a stereoscopic image is displayed only by the horizontal parallax thereof ~~by the relinquishment of~~, with the vertical parallax thereof being relinquished. In this case, ~~similarly~~ similar to ~~what have been~~ that described above, for example, when the diffraction angle [[è]]θ is set to be 30 degrees and the reproduced wavelength [[ë]]λ is set to be 0.5 [[im]] μm, the total number N_{hv} of the required samples is $2dL \times 10^6$ in accord ~~conformity~~ with Equation 5. If the horizontal length d and the vertical length w of a stereoscopic image to be displayed are ~~severally set to be~~ 100 mm and the vertical resolution L is set to be 1000, the total number N_h of the samples necessary for displaying one piece of stereoscopic image is 2×10^8. This amount of information is ~~1/100 in comparison with~~ 1/100th of the aforesaid total sample number N_{hv}[[,]] (i.e., 2×10^{10}). According to the present embodiment, using the technique shown in Fig. 3, it is possible to decrease the amount of information and processing time necessary for displaying a stereoscopic image at a practical level. Also, because two human eyes exist in a horizontal line, human eyes are less sensitive to vertical parallax than to horizontal parallax.

Thus, stereoscopic effects may fully be expressed in the case where a stereoscopic image is displayed by the use of the technique shown in Fig. 3, with its vertical parallax being relinquished.

~~According to the present embodiment using the technique shown in Fig. 3, it becomes possible to decrease an amount of information and a processing time, both being necessary for displaying a stereoscopic image, to a practical level.~~

~~Incidentally, even in the case where a stereoscopic image is displayed by the use of the technique shown in Fig. 3, with its vertical parallax being relinquished, because two human eyes exist in a horizontal line, human eyes are more insensitive to the vertical parallax than horizontal parallax, and thereby stereoscopic effects may fully be expressed.~~

Next, according to ~~still~~ another embodiment of the present invention, a display apparatus 30 shown in Fig. 4 is provided for displaying a stereoscopic image. The display apparatus 30 displays stereoscopic images by scanning and projecting light modulated by a micromachine type one-dimensional spatial modulator ~~by utilizing the aforesaid principle of the present invention~~. The display apparatus 30 comprises a first laser oscillator 31a, a second laser oscillator 31b, and a third laser oscillator 31c that respectively emits a laser beam in the wavelength range of red, green and blue. Other types of coherent light sources such as solid state

laser device may be employed in place of the laser oscillators. The display apparatus 30 further comprises a GLV 32 for modulating the laser beams emitted from the laser oscillators 31a, 31b, 31c so as to form one-dimensional wavefronts Wr, Wg, Wb with desired phase distributions.

~~The display apparatus 30 comprises, as shown in Fig. 4, a first laser oscillator 31a, a second laser oscillator 31b and a third laser oscillator 31c that respectively emits a laser beam in each wavelength range of red, green and blue, respectively. The display apparatus 30 further comprises a GLV 32 for modulating the laser beams emitted from these laser oscillators 31a-31c so as to form one-dimensional wavefronts with respectively desired phase distributions.~~

~~Alternatively, other types of coherent light sources such as solid state laser device may be employed in place of the laser oscillators.~~

The GLV 32 is provided with three ribbon arrays 32a, 32b, 32c respectively formed from a plurality of minute ribbons that are one-dimensionally arrayed (in a straight line). In the GLV 32, each ribbon 32a, 32b, 32c is structured to be able to ascend and descend independently and ~~arbitrary~~ arbitrarily by use of a piezoelectric device or the like. ~~These~~ The ribbons 32a, 32b, 32c in the GLV 32 are independently driven by a control circuit that will be described later. ~~Moreover,~~

~~each~~ Each ribbon array 32a, 32b, 32c of the GLV 32 is irradiated by a red laser beam, a green laser beam, or a blue laser beam that is respectively radiated from the first, the second, or the third laser oscillators 31a, 31b, 31c. That is, in the GLV 32, a ribbon array 32a for red, a ribbon array 32b for green, and a ribbon array 32c for blue are formed, and the red laser beam, the green laser beam, and the blue laser beam are selectively radiated. Then, the GLV 32 one-dimensionally modulates and reflects each laser beam to generate an arbitrary wavefront for each color: a red wavefront Wr, a green wavefront Wg, and a blue wavefront Wb shown in Fig. 4. Because the color wavefronts Wr, Wg, Wb travel through substantially the same optical path, they are collectively referred to as a laser beam in the following sections of the present specification.

~~That is, in the GLV 32, a ribbon array 32a for red, a ribbon array 32b for green, and a ribbon array 32c for blue are formed, and the red laser beam, the green laser beam or the blue laser beam is respectively radiated. Then, the GLV 32 one-dimensionally modulates and reflects each laser beam to generate an arbitrary wavefront at every color as red wavefront Wr, green wavefront Wg and blue wavefront Wb shown in Fig. 4. Because respective color wavefronts Wr, Wg, Wb that have been generated in such a way that they travel through substantially the same optical path, each color laser beam is named generically and simply as a laser beam in the following sections of the present specification.~~

Moreover, the display apparatus 30 comprises a collimator lens 33, a first galvano-mirror 34, a second galvano-mirror 35, a Fourier transformation lens 36, and ~~an~~ a one-dimensional diffuser panel 37, ~~all being~~ arranged in this order on an optical path of the laser beams reflected by the GLV 32. The collimator lens 33 allows the laser beams reflected by the GLV 32 to pass through to form parallel rays. The parallel rays leaving the collimator lens 33 are then incident on the first galvano-mirror 34. The first galvano-mirror 34 reflects the incident laser beams to make them incident on the second galvano-mirror 35. The second galvano-mirror 35 reflects the incident laser beams to make them incident on the Fourier transformation lens 36.

~~The collimator lens 33 allows the laser beams reflected by the GLV 32 to pass through to form parallel rays, and the parallel rays is incident on the first galvano-mirror 34. The first galvano-mirror 34 reflects the incident laser beams to make them incident on the second galvano-mirror 35. The second galvano-mirror 35 reflects the incident laser beams to make them incident on the Fourier transformation lens 36.~~

Rotations of the first and the second galvano-mirrors 34, 35 are controlled by a control circuit that will be described later. Assuming an xyz coordinate system as shown in Fig. 5, the first galvano-mirror 34 is controlled to rotate about the z-axis, and the second galvano-mirror 35 is controlled to rotate about the x-axis. That is, the first and the second galvano-mirrors 34, 35 have rotation axes

orthogonal to each other, and they are driven to rotate about respective rotation axes under the control of the control circuit.

~~Accordingly, in the display apparatus 30, the laser beams, that have modulated by the GLV 32 and have one-dimensional wavefronts (linear wavefronts), are scanned by the first and the second galvano-mirrors 34, 35 in such a way, for example, shown in Fig. 6.~~ Fig. 6 ~~schematically~~ shows the scanning directions of the laser beams in a projection plane on which stereoscopic images are projected by the display apparatus 30. In the figure, the transverse direction is assumed as the horizontal direction, and the longitudinal direction is assumed as the vertical direction. That is, in the display apparatus 30, the first and the second galvano-mirrors 34, 35 are driven to rotate by the control circuit and, thereby, can scan the incident laser beams in the horizontal direction and the vertical direction, respectively.

~~That is, in the display apparatus 30, the first and the second galvano-mirrors 34, 35 are driven to rotate by the control circuit, and thereby they can scan the incident laser beams in the horizontal direction and the vertical direction, respectively.~~

Because the laser beams modulated by the GLV 32 have one-dimensional wavefronts ~~in the display apparatus 30~~, stereoscopic images may be displayed by ~~the~~ scanning ~~of~~ the

laser beams only with the second galvano-mirror 35 in the direction perpendicular to the laser beam wavefronts[[,]] (i.e., in the vertical direction in Fig. 6), without using the first galvano-mirror 34. In this case, the horizontal length of the stereoscopic image to be displayed is restricted by the length of the ribbon arrays 32a, 32b, 32c formed on the GLV 32.

~~More specifically, when~~ When a GLV capable of displaying 1024 pixels is used as the GLV 32 in the display apparatus 30, ~~the number of~~ there are 6,144 ribbons ~~formed~~ in each ribbon array 32a, 32b, 32c in the GLV 32 ~~are severally 6144~~ (~~in the case~~ where six ribbons are included in one pixel). ~~In the GLV 32, when~~ When it is assumed that an interval distance between two neighboring ribbons is 5 [[ìm]] μm, the horizontal length of a stereoscopic image capable of being projected by the display apparatus 30 ~~becomes~~ is about 30 mm unless a magnifying lens is used. Accordingly, it is necessary to increase the number of ribbons of the GLV 32 in order to widen the horizontal length of the stereoscopic image. However, the yield of manufacturing is decreased and the manufacturing cost increased when the device area of the GLV 32 is enlarged.

~~Accordingly, it is necessary to increase the number of ribbons of the GLV 32 in order to widen the horizontal length of the stereoscopic image. On the other hand, the yield of manufacturing may be decreased and the manufacturing cost may~~

~~be increased if the device area of the GLV 32 is to be enlarged.~~

~~Because~~ When, in the display apparatus 30, the laser beams are scanned by the first and the second galvano-mirrors 34,35 in the horizontal direction and in the vertical direction~~. Namely~~, the laser beams are, so to speak, two-dimensionally scanned. Accordingly, the horizontal length of the stereoscopic image to be displayed may be enlarged without depending on the length of the ribbon arrays 32a, 32b, 32c formed on the GLV 32.

When the operation frequencies of the first and the second galvano-mirrors 34, 35 are 1 MHz, 200 lines may be scanned by the first galvano-mirror 34 in the horizontal direction even if 5,000 lines are scanned by the second galvano-mirror 35 in the vertical direction. Accordingly, ~~as described above,~~ when the GLV 32 on which 6,144 ribbons are formed with intervals of 5 [[ìm]] µm between each other is used, the horizontal length of the stereoscopic image to be displayed may be enlarged up to 6 m.

Because the amount of information to be processed naturally increases ~~by leaps and bounds~~ considerably for the displaying of a stereoscopic image in a large size as described ~~above~~, the ~~practically~~ realizable image size is limited depending on the performance of signal processing. The display apparatus 30 according to the

present embodiment is ~~sufficiently~~ capable of displaying a stereoscopic image in the aforesaid ~~degree of~~ size. By ~~alleviating the limitation due to the~~ improving signal processing capability by, for example, utilizing a parallel processing technique of a high performance computer apparatus ~~having high operation performance~~, an extra-large three-dimensional image may also be displayed.

It is difficult to scan the laser beams precisely in the horizontal direction and in the vertical direction as shown in Fig. 6 because the first and the second galvano-mirrors 34, 35 are driven to rotate continuously in the present embodiment. Alternatively, by changing the ~~change of~~ scanning speeds of the first and the second galvano-mirrors 34, 35 in the display apparatus 30 ~~as shown in Fig. 7~~, laser beams may be scanned obliquely, as shown in Fig. 7. More specifically, for example, the laser beam may be scanned six times in the vertical direction by the second galvano-mirror 35 while the laser beam has been scanned once in the horizontal direction by the first galvano-mirror 34. However, because the one-dimensionally modulated laser beam is shifted in the horizontal direction while the laser beam is scanned in the vertical directions in this case, an amount of such shifting should be ~~in~~ taken into consideration ~~to drive~~ for driving the ribbon arrays 32a, 32b, 32c of the GLV 32.

In the display apparatus 30, by the aforesaid operation of the first and the second galvano-mirrors 34, 35, the laser beams are scanned in the horizontal direction and the vertical direction. Then, the scanned laser beams ~~is~~ are incident on the Fourier transformation lens 36. Other types of lens may be employed in place of the Fourier transformation lens 36 as long as such lens can perform Fourier transformation on the desired light. The Fourier transformation lens 36 alters the laser beams passing through it according to the Fourier transformation. Then, the transformed laser beams are incident on the one-dimensional diffuser panel 37.

~~The Fourier transformation lens 36 makes the incident laser beams pass through it to transform them by the Fourier transformation. Then the Fourier transformation lens 36 makes the transformed laser beams be incident on the one-dimensional diffuser panel 37.~~

~~Alternatively, other types of lens may be employed in place of the Fourier transformation lens 36 as long as such lens can perform Fourier transformation on the desired light.~~

The one-dimensional diffuser panel 37 is disposed on a Fourier surface of the Fourier transformation lens 36[[,]] and ~~the one-dimensional diffuser panel 37 makes~~ diffuses the ~~incident~~ laser beams ~~pass~~ passing through it ~~to diffuse them~~

one-dimensionally. Because the display apparatus 30 is provided with the one-dimensional diffuser panel 37, ~~the display apparatus 30~~ a slightly ~~enlarges the~~ enlarged visual field ~~thereof~~ is obtainable in the vertical direction, ~~and~~ which can make the discontinuities between the wavefronts of the laser beams ~~that are~~ scanned in the vertical directions inconspicuous, thereby realizing more natural stereoscopic effects. After passing through the one-dimensional diffuser panel 37, the laser beams are projected on a projection plane and a stereoscopic image G having horizontal parallax is displayed, as shown in Fig. 4.

~~Then, in the display apparatus 30, the laser beams passed through the one-dimensional diffuser panel 37 is projected on a projection plane as shown in Fig. 4, and a stereoscopic image G having horizontal parallax is displayed.~~

The display apparatus 30 comprises a control circuit 40, as shown in Fig. 8. The control circuit 40 ~~is constituted by~~ includes, for example, various semiconductor devices. The information (hereinafter referred to as display image data) concerning stereoscopic images to be displayed is input into the control circuit 40. The information may be from an apparatus ~~that may be~~ located outside the display apparatus 30. The control circuit 40 controls the GLV 32 according to the input display image data to drive the plural ribbons formed on the GLV 32 separately. Moreover, the control circuit 40 controls the rotation speeds and the rotation timings of the first and the second galvano-mirrors 34, 35.

The control circuit 40 ~~is~~ can comprise, for example ~~as shown in Fig. 8~~, ~~comprises~~ a clock generator 41, a Fourier transformation section 42, a GLV driving section 43, and a galvano-mirror driving section 44. The clock generator 41 generates a clock signal for referencing the operation timing of the control circuit 40 and the whole operation timing of the display apparatus 30. The clock generator 41 outputs the generated clock signal to the GLV driving section 43 and the galvano-mirror driving section 44. The signal level of the clock signal can be set to change in a predetermined manner. Each section of the control circuit 40 performs various kinds of processing at the timing of the signal level change of the clock signal.

~~The clock generator 41 generates a clock signal being a reference of the operation timing of the control circuit 40, and the whole operation timing of the display apparatus 30. The clock generator 40 outputs the generated clock signal to the GLV driving section 43 and the galvano-mirror driving section 44. The signal level of the clock signal changes, for example, every predetermined time. Each section of the control circuit 40 performs various kinds of processing at the timing of the signal level change of the clock signal.~~

The Fourier transformation section 42 receives display image data from an external apparatus, and performs the Fourier transformation processing of the display image data.

Then, the Fourier transformation section 42 outputs the data after performing the Fourier transformation processing to the GLV driving section 43.

The GLV driving section 43 operates at a timing based on the clock signal input from the clock generator 41, and controls the GLV 32 in accordance with the data input from the Fourier transformation section 42. That is, the GLV driving section 43 drives each ribbon formed on the GLV 32 to ascend or to descend, and sets each ribbon array 32a, 32b, 32c of the GLV 32 at a desired position that corresponds to a phase distribution in accordance with the input data.

The galvano-mirror driving section 44 controls the rotations of the first and the second galvano-mirror 34 according to the timing based on the clock signal input from the clock generator 41.

~~The control circuit 40 has the following control function.~~ That is, by the operation of the GLV driving section 43 and the galvano-mirror driving section 44 according to the clock signal, the control circuit 40 ~~makes~~ causes the GLV 32 and the first and the second galvano-mirrors 34, 35 to operate at suitable timings in cooperation with each other. When the laser beams are scanned under the ~~above cited~~ control of the control circuit 40, ~~an~~ a stereoscopic image is displayed in the display apparatus 30, as shown in Fig. 6 or Fig. 7.

The display apparatus 30 structured in such a way uses a micromachine type one-dimensional spatial modulator, i.e. the GLV 32, as a spatial modulator for modulating light to be projected. Because the GLV 32 can be operated at an extremely high speed, an abundant amount of information may be used to display the stereoscopic image ~~may be displayed while using sufficiently abundant amount of information~~. Moreover, because the display apparatus 30 displays the stereoscopic image with the light modulated by the GLV 32, the overall structure of the apparatus may be simplified, and the manufacturing cost thereof may be lowered. Moreover, stereoscopic effects may be expressed without using special equipment such as dedicated glasses for viewing a stereoscopic image.

Moreover, the display apparatus 30 modulates the laser beams with the GLV 32 having a function of ~~an~~ a one-dimensional spatial modulator[[,]] and projects the modulated laser beams while scanning them to predetermined directions. Thereby, the display apparatus 30 displays the stereoscopic image. That is, the display apparatus 30 relinquishes the vertical parallax in the stereoscopic image to be displayed[[,]] and displays the stereoscopic image only with its horizontal parallax. Since the display apparatus 30 displays the stereoscopic image by utilizing only the horizontal parallax, the display apparatus 30 may suppress the increase of the amount of information necessary for displaying the stereoscopic image.~~, and thereby~~ Thereby, it becomes possible to decrease the amount of information and ~~the~~ processing time~~,~~

~~both being~~ necessary for displaying the stereoscopic image.

In the above description, the display apparatus 30 scans the laser beams in the horizontal direction and in the vertical direction ~~with~~ using the first and the second galvano-mirrors 34, 35. ~~, and consequently~~ In this way, the display apparatus 30 functions, so to speak, as a scan mechanism for scanning the laser beams.

The display apparatus 30 is not limited to ~~be~~ being equipped with the scan mechanism structured ~~in such a way~~ as described. ~~Alternatively, any~~ Any scan mechanism structured to scan and project laser beams in predetermined directions may be ~~employable~~ used. More specifically, for example, the scan mechanism may be structured by the use of a two-axis galvano-mirror having rotational axes orthogonal to each other and able to be driven two-dimensionally.

~~More specifically, for example, the scan mechanism may be structured by the use of a two-axis galvano-mirror that is equipped with rotational axes orthogonal to each other and may drive a mirror two-dimensionally.~~

Moreover, ~~still~~ as another type of the scan mechanism, a mirror array 50, as shown in Fig. 9, may be used. In the mirror array 50, ~~as shown in Fig. 9,~~ surfaces on which the laser beams are incident upon are formed in a multistage shape. The reflection angle of each stage mirror is formed to differ from each other slightly. Then, by the use of the mirror array

50 in combination with, for example, the first galvano-mirror 34, the scanning with the scan mechanism is accomplished. In this case, for example, by rotating the galvano-mirror 34 about the horizontal axis, the laser beams are scanned in the direction of an arrow A (i.e., in the vertical direction). Then, the laser beams are incident on the reflection surfaces of the mirror array 50 and scanned in the direction of an arrow B in Fig. 9, namely the direction of a combination of the vertical direction and the horizontal direction, on a projection plane 51.

~~In this case, for example, by the rotation driving of the galvano-mirror 34 about the horizontal axis, the laser beams are scanned in the direction of an arrow A in Fig. 9, i.e. the vertical direction. Then, the laser beams are incident on the reflection surfaces of the mirror array 50, and thereby the laser beams are scanned in the direction of an arrow B in Fig. 9, namely the direction of a combination of the vertical direction and the horizontal direction, on a projection plane 51.~~

Moreover, in the display apparatus 30, the scan mechanism may be structured by the combination of, for example, a polygon mirror and a volume type hologram. Alternatively, the display apparatus may be structured to scan the laser beams by the rotation of the GLV 32 itself ~~with~~ utilizing a rotation mechanism such as a stepping motor.

Although the invention has been described in its

preferred ~~form~~ forms with a certain degree of particularity, ~~obviously many~~ changes, variations, and combinations of the embodiments are possible therein. It is therefore to be understood that the present invention may be practiced other than as specifically described herein without departing from the scope of the invention ~~thereof~~.

ABSTRACT OF THE DISCLOSURE

A stereoscopic image display apparatus is provided. The apparatus comprises a light source radiating light with a predetermined wavelength range, an one-dimensional spatial modulator including one-dimensionally arranged elements that are independently driven to generate an arbitrary phase distribution, and a scan unit scanning the light from the light source to a predetermined direction, the light having entered into the one-dimensional spatial modulator and having been modulated therein.